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## Vickers Hardness Sensitivity Coefficients

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ISO 6507-1 defines the Vickers hardness value,  $HV$ , as:

$$HV = 0.102 \times \frac{2F \sin\left(\frac{\alpha}{2}\right)}{d^2}$$

where:

$F$  = force (in N)

$\alpha$  = plane angle of the indenter ( $136^\circ$ )

$d$  = mean indentation diagonal length (in mm)

Partial derivatives allow the sensitivity coefficients for force, indenter angle and indentation diagonal length to be determined:

$$\frac{\partial HV}{\partial F} = \frac{HV}{F}$$

$$\frac{\partial HV}{\partial \alpha} = \frac{HV}{2 \tan\left(\frac{\alpha}{2}\right)}$$

$$\frac{\partial HV}{\partial d} = -2 \times \frac{HV}{d}$$

Graphs showing values of these three sensitivity coefficients against hardness are given below:

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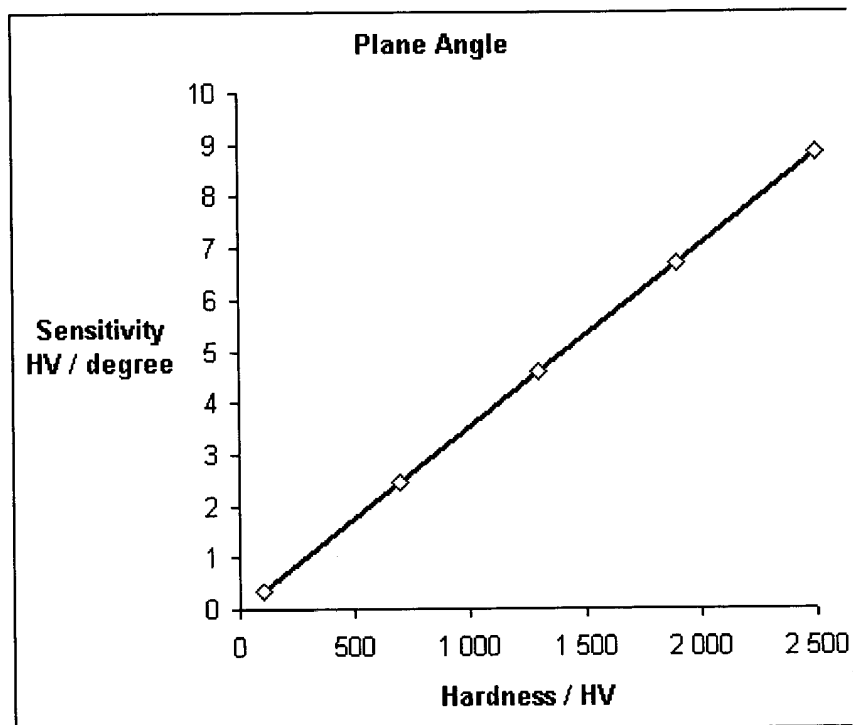
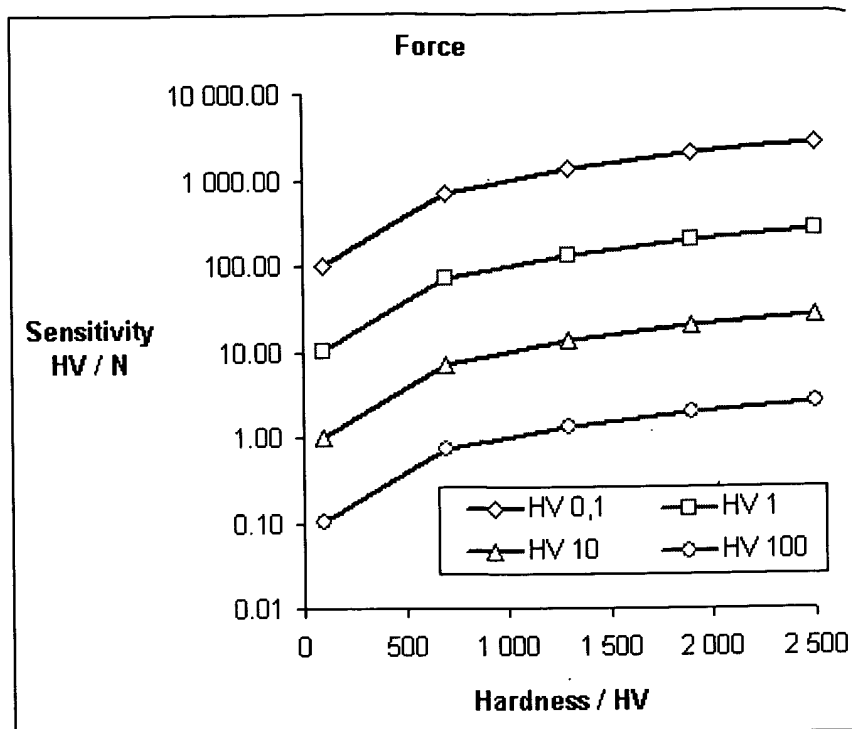
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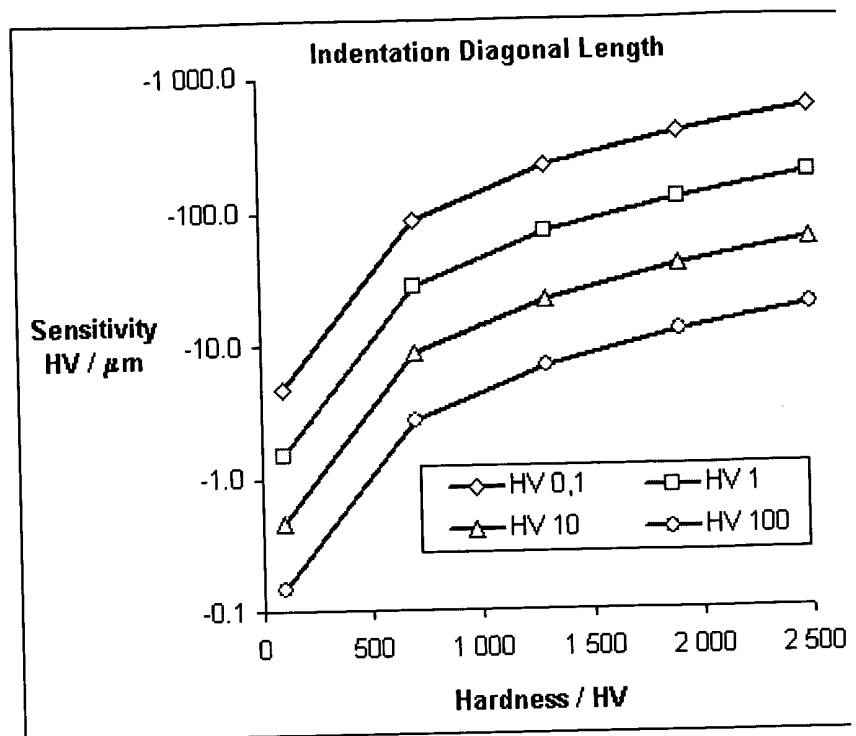
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Geometrical considerations allow the sensitivity coefficients for tip radius of line of junction to be approximated:

$$\frac{\partial HV}{HV} = -0.3 \left( \frac{r}{d} \right)^3$$

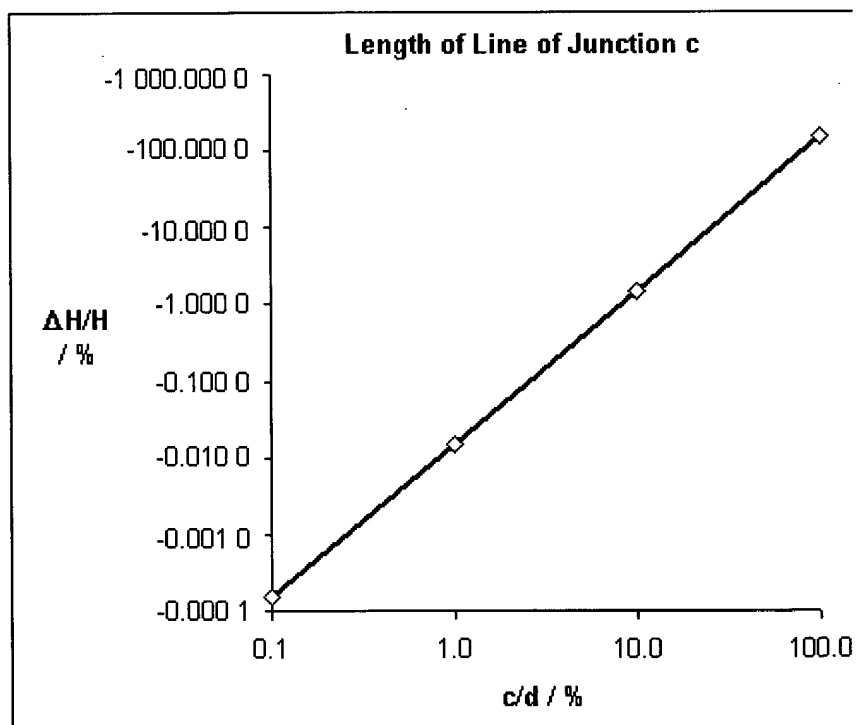
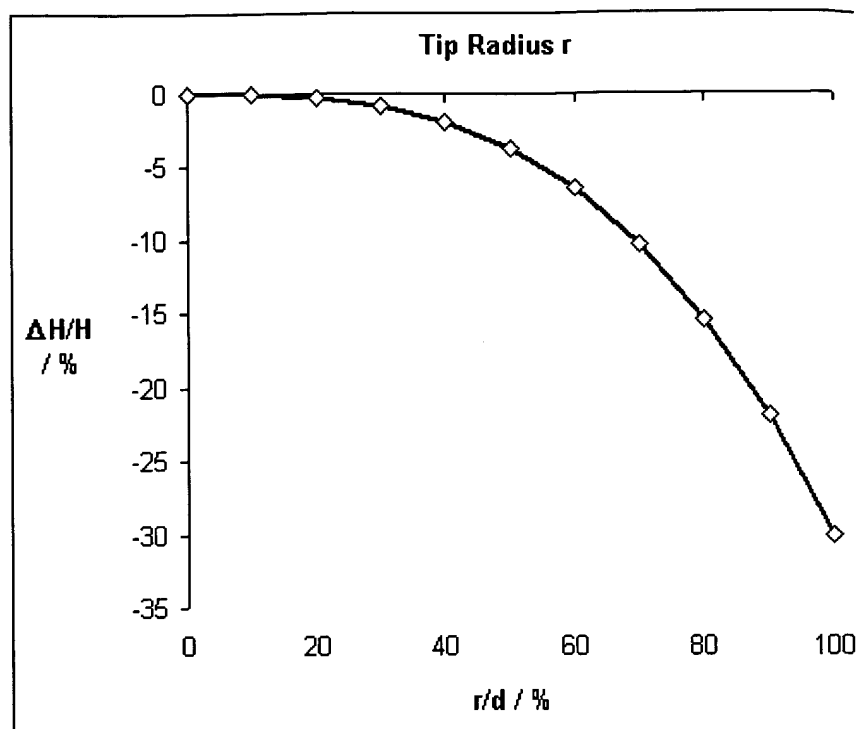
$$\frac{\partial HV}{HV} = -1.5 \left( \frac{c}{d} \right)^2$$

where:

$r$  = tip radius (in mm)

$c$  = length of line of junction (in mm)

The assumption made in both cases is that the volume of the indentation the same, for varying values of  $r$  and  $c$ , as would be the case with an ind perfect geometry. Graphs showing values of these two parameters are gi



Practical experiments were carried out, for the HV 10 and HV 30 ranges, determine the sensitivity coefficients for loading time and test force duration addition, the sensitivities to force value were also determined, to see how agreed with the theoretical values.

#### Sensitivity to application time and force duration

ISO 6507-1 specifies that, for forces of 49.03 N (HV 5) and above, "the initial application of the force until the full test force is reached shall be less than 2 s nor greater than 8 s" and that "the duration of the test force shall be less than 15 s".

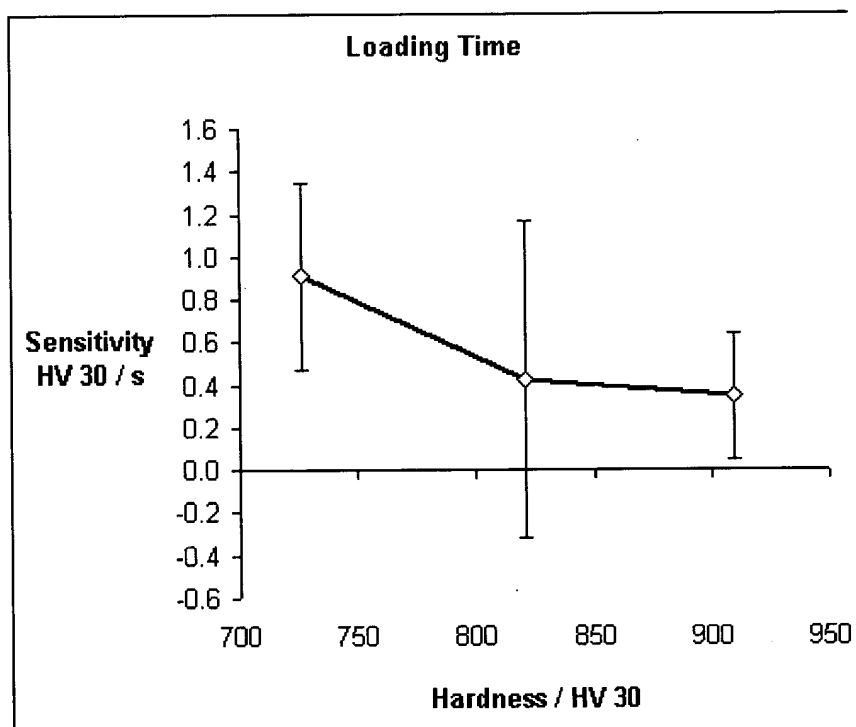
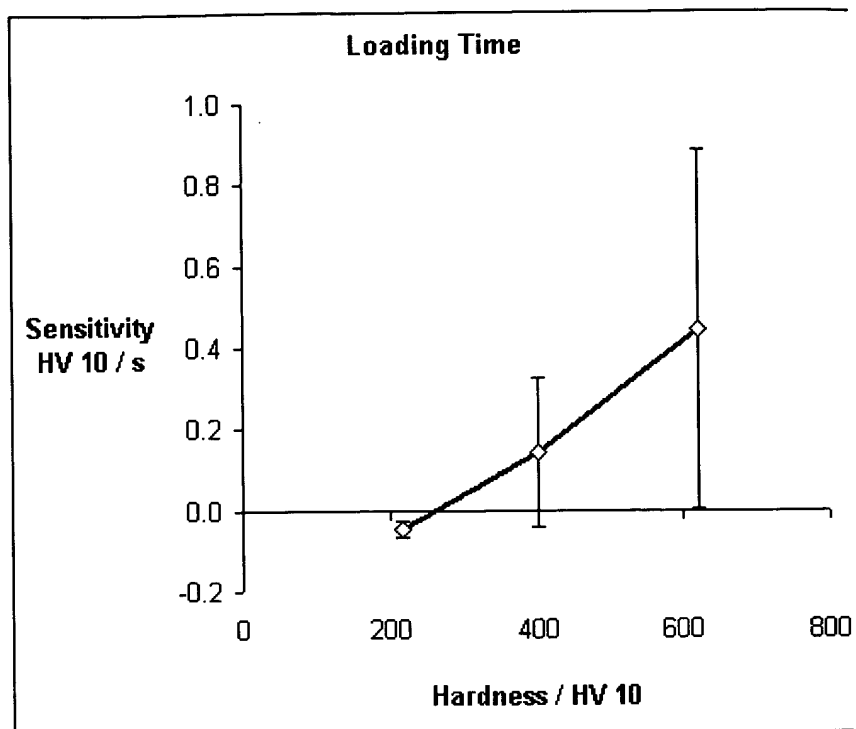
For both ranges, five hardness tests were carried out on each of three blocks of different nominal hardnesses, at different values of the input parameter:

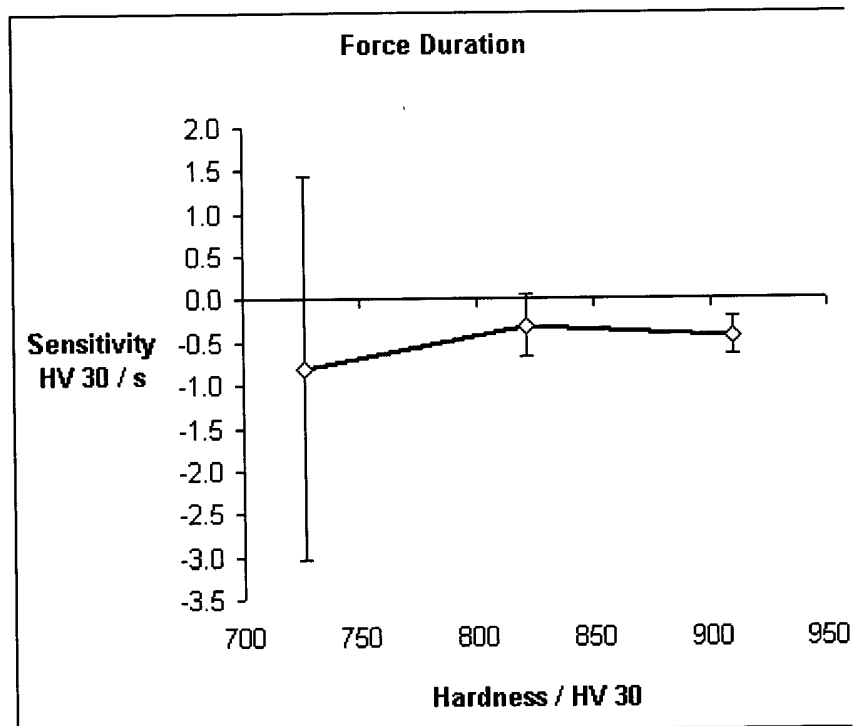
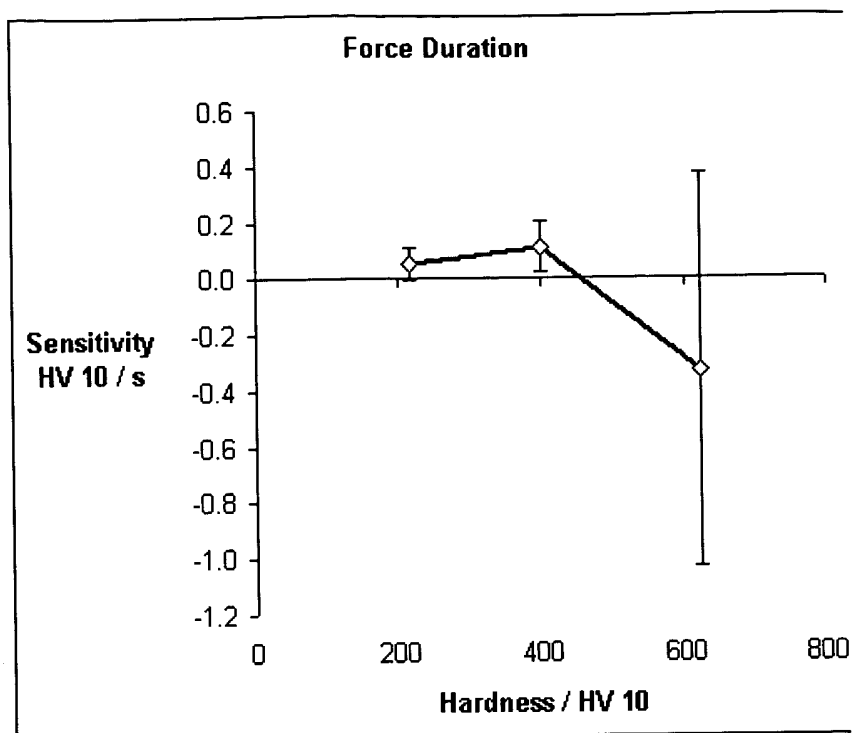
Range	Force	Parameter	Value 1	Value 2	Value 3
HV 10	98.07 N	Application time	2 s	4 s	6 s
		Force duration	10 s	13 s	15 s
HV 30	294.2 N	Application time	2 s	4 s	6 s
		Force duration	10 s	13 s	15 s

The forces were not applied in a single linear profile, but in two linear sections: 80 % of the force in 25 % of the time followed by the final 20 % of the force remaining 75 % of the time:

Range	Application time	Part 1			Part 2		
		Force	Time	Rate	Force	Time	
HV 10	2 s	78.46 N	0.5 s	156.9 N·s <sup>-1</sup>	19.61 N	1.5 s	1
	4 s		1.0 s	78.46 N·s <sup>-1</sup>		3.0 s	6
	6 s		1.5 s	52.30 N·s <sup>-1</sup>		4.5 s	4
	8 s		2.0 s	39.23 N·s <sup>-1</sup>		6.0 s	3
HV 30	2 s	235.4 N	0.5 s	470.7 N·s <sup>-1</sup>	58.8 N	1.5 s	3
	4 s		1.0 s	235.4 N·s <sup>-1</sup>		3.0 s	1
	6 s		1.5 s	156.9 N·s <sup>-1</sup>		4.5 s	1
	8 s		2.0 s	117.7 N·s <sup>-1</sup>		6.0 s	9

For each of the three hardness blocks, the mean measured hardness was plotted against the input parameter (application time or force duration) and a linear least squares fit was applied to the data. The gradient of this line (the sensitivity coefficient) was plotted against hardness for the three hardness values and these values are shown in the following graphs. The error bars relate to the linearity of the fit of hardness against input parameter at each of the hardness values – each error bar is  $\pm 2 \times$  the standard error associated with the estimate of the gradient (sensitivity coefficient).





### Sensitivity to force value

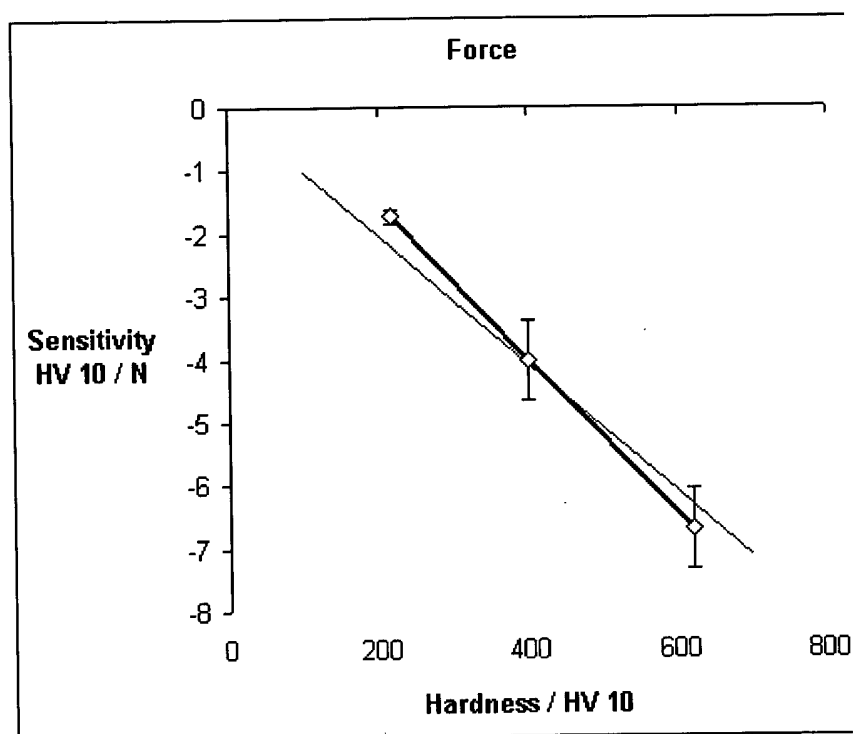
ISO 6507-2 specifies that, for forces of 1.961 N (HV 0.2) and above, each force verification measurements in the machine (made by an ISO 376 Class proving device) shall agree with the nominal force to within a tolerance of

For both ranges, five hardness tests were carried out on each of three blocks

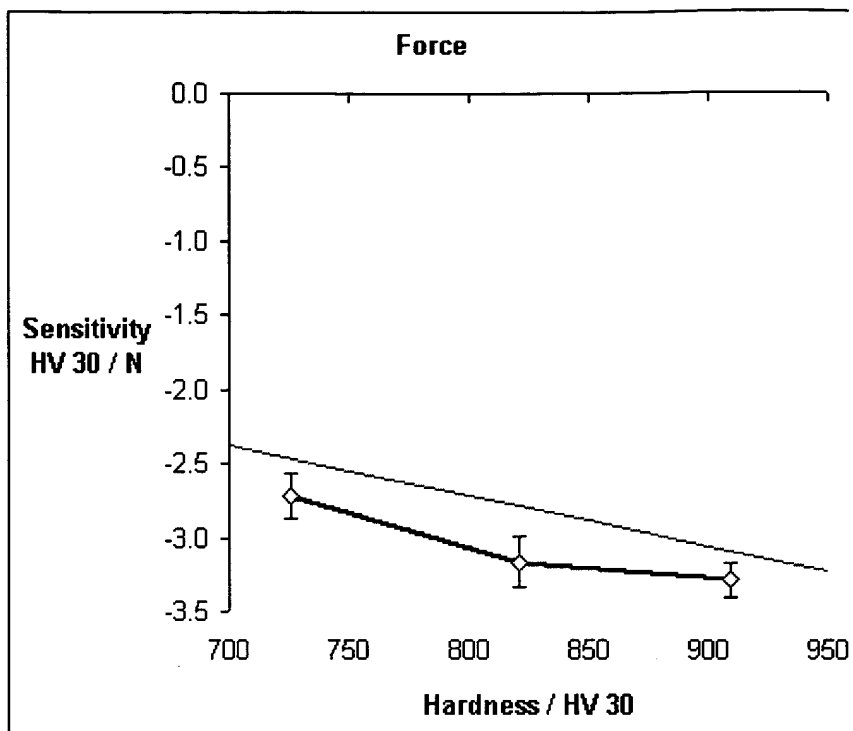
different nominal hardnesses, at different values of force:

Range	Force		
	Run 1	Run 2	Run 3
HV 10	96.60 N	98.07 N	99.54 N
HV 30	287.79 N	294.20 N	298.61 N

For each of the three hardness blocks, the mean measured hardness (calculated using the nominal force) was plotted against applied force and a linear least squares fit was applied to the data. The gradient of this line (the sensitivity of hardness to force) was plotted against hardness for the three blocks, and the values are shown in the following graphs. The error bars relate to the line of the fit of hardness against force at each of the hardness values – each error is  $\pm 2 \times$  the standard error associated with the estimate of the gradient (sensitivity coefficient). The red lines are plots of the sensitivity coefficients obtained by taking a partial derivative of the hardness equation – they are plotted as negative values, rather than positive ones (as the equation suggests), because the values are calculated from the nominal force and the actual indentations, rather than from the actual force and the indentation size at nominal force.







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